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LESSONS LEARNED FROM THE DEVELOPMENT AND TRANSITION OF THE AIR INTERCEPT TRAINER (AIT)

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The Aircrew Training Research Division of Armstrong Laboratory conducted a study of the transition of the Air Intercept Trainer (AIT) to the pilot training community. The study was conducted to improve training technology and to better understand how to transition technology from the laboratory to the user. User groups were: Air National Guard (ANG) squadrons, Air Combat Command (ACC) training squadrons, and Air Force Reserve (AFRES) operational squadrons. This technical report documents major lessons learned about device utilization, technology design, user acceptance, training effectiveness and other issues of transition. Findings showed that the AIT was highly successful as a training device in the ANG and ACC squadrons, but was less successful in the AFRES operational squadrons.

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PREFACE

This report documents work completed on the study of technology transition as a process for improving training methods and technology from Armstrong Laboratory to user/customers. Specifically, it examines the application of a low-cost, part-task trainer in three pilot communities. Results of observation of device usage, data from interviews and questionnaire surveys of users, and training effectiveness data are synthesized and contained in the report. Current aircrew training areas and practices which may benefit from this research include:

1. Unit-level training requirements and objectives

2. Application of simulation-based training devices

3. Training technology transition

The work was accomplished under Work Unit 1123-25-15, Unit Level Training Research Applications. The project scientist was Dr. Bernell J. Edwards.

LESSONS LEARNED FROM THE DEVELOPMENT AND TRANSITION OF THE AIR INTERCEPT TRAINER (AIT)

EXECUTIVE SUMMARY

This report documents lessons learned from an effort to transition the air intercept trainer (AIT) as new training technology from the Armstrong Laboratory, Aircrew Training Research Division (AL/HRA) to Air Force users. The development and transition period spanned more than six years during which design concepts evolved permitting the fusion of emerging technology with changing user interests and needs. This report deals more specifically with findings from the perspective of AIT users, rather than from an engineering development point of view, although some of the latter aspects have been included. The report presents a summary of the major lessons learned from the effort as contained in this executive summary. For readers interested in additional detail on findings, this report provides background and elaboration of findings, beginning on page 9.

The lessons learned are grouped and presented in order of the development and transition of the AIT to three groups of users. The first user group was the Air National Guard (ANG), 162nd Training Squadron (TS), Tucson, Arizona. The second period of transition involved the Air Combat Command (ACC), 58th Tactical Training Squadron, Luke AFB, AZ for F-16 initial qualification pilot training. The third period of development represented an extension of the AIT training concept into the operational F-16 community of the Air Force Re3erve (AFRES). This third period also included expanded use of the trainer by the Air National Guard. Each of these development and transition periods yielded a variety of data and lessons learned upon which subsequent improvements in the device were made possible.

Finally, a review of the major issues investigated and the relevant lessons learned for each issue is presented as a conclusion to this report.

Trainer Description

The original air intercept trainer prototype was developed as a technology testbed device to support Air National Guard conversion training from the A-7D to the F-16A aircraft. The purpose of the AIT was to train pilots to perform the beyond-visual-range portion of air intercepts which accounts for about 90% of these maneuvers. The AIT consisted of a quasi-cockpit equipped with a head-up display (HUD), a radar electro-optical display (REO), throttle quadrant, and side-stick controller. The trainer simulated basic aerodynamic and selected avionics capabilities of the F-16 aircraft required in performing intercepts. AIT development evolved through three basic models or configurations spanning approximately six years.

The original AIT prototype simulated selected aspects of the F-16A model aircraft and was later modified to simulate the F-16C model aircraft. The original trainer permitted the student limited control of HUD and radar modes of operation, but did not permit pilot control of simulated flight. Rather, a computer model of an idealized intercept was flown for the pilot by the trainer. However, soon after its introduction in the squadron, the prototype was upgraded to provide realtime flight controls for the pilot. Training software in the AIT contained practice scenarios of varying complexity. Using these scenarios pilots learned to acquire and intercept simulated enemy aircraft.

A second major upgrade in the AIT occurred about two years following its introduction to the ANG. This version included expanded and improved training scenarios including radar targets with maneuvering capabilities, improved feedback and debriefing capabilities for training purposes, and a forward field-of-view display of the flight environment.

A third version of the AIT followed about two years after version two. This AIT incorporated enhancements intended to support the training requirements of operational units in the Air Force Reserve. Enhancements included more capable maneuvering targets, more complex training scenarios, and the capability to electronically link or "network" two AITs so that pilots could simulate two-ship intercepts. For a more complete description of the AIT, see Boyle and Edwards, 1992 (Fig. 1).

Technology Transition Issues

From the outset, the intention of the laboratory was a joint effort with users not only to improve the training device itself, but also to understand and improve the capability of AL/HRA to transition technology to users. In general, the effort included a continuing and long-term dialog with users. In attempting to understand the process, several component issues were identified and incorporated to guide collection of meaningful data. These included user acceptance of the device, usage methods/patterns, design features and options, training capability and effectiveness, device reliability, technology development, and technology transition.

Data Collection

Data were collected over an extended period of time during which the AIT was installed as a training testbed with various users. Types of data collected included observations made by

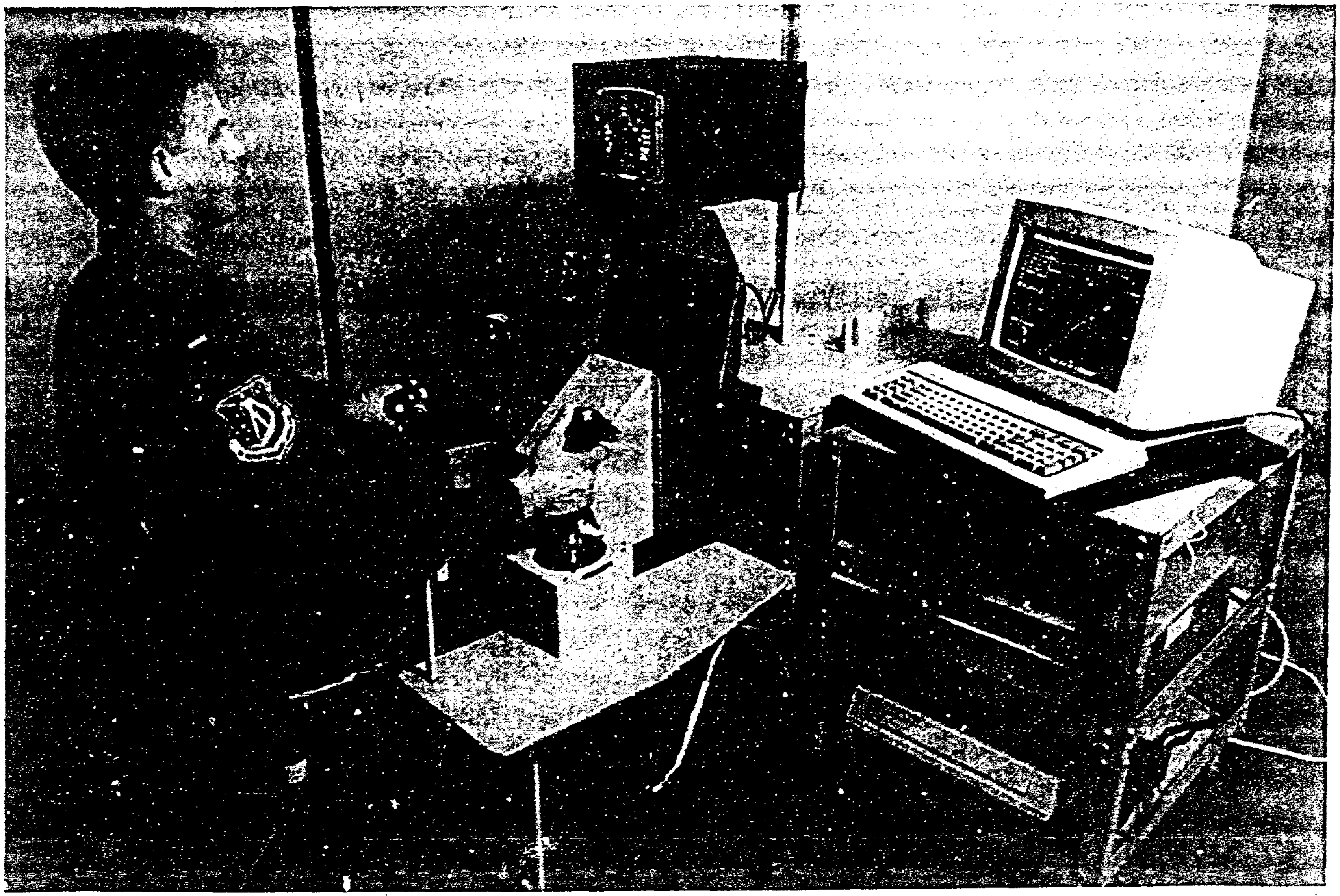

Figure 1. AIT Trainer

AL/HRA investigators at testbed locations, questionnaires, interviews, and two experimental studies of training effectiveness.

Lesson Learned from the ANG Experience

The first AIT prototype was installed at the ANG Tucson to support the conversion course. It was adopted as a standard part of the training syllabus. During the ensuing two-year period, the AIT as applied by the user to the ANG pilot training program was the subject of intensive study by AL/HRA.

1. User Acceptance and Training Evaluation Results. The training capabilities and utility of the AIT were well accepted by the Air National Guard training squadron and the device became a key training resource during the squadron's conversion to the F-16A aircraft from the A-7D aircraft.

Laboratory investigators used observational and interview techniques to evaluate device training utility. Extensive study of the methods used by instructors in training students with the device was conducted. Interviews of pilots, instructors, and students, were also conducted. Analysis of the data collected clearly showed a high rate of user acceptance of the trainer within the squadron. Both student and instructor opinion was positive regarding the training utility of the device for conversion training. Instructors liked the unique capability afforded by the device to manipulate the avionics systems via the instructor console in order to teach radar employment and intercept geometry. Students appreciated the opportunity to become familiar and proficient on basic skills such as switchology before attempting intercepts in the aircraft.

2. Familiarization Training. Students required considerable instructor-assisted training to learn basic operation of the AIT. However, once students were familiar with the equipment and could "navigate" within the software, self-paced practice on the device became a realistic option.

The original version of the operator's manual provided with the prototype trainer proved to be inadequate in scope and content for purposes of enabling students to operate the trainer. Instructors found it necessary to devote about an hour per student to insure adequate familiarization. Additional instructional materials were developed to supplement the operator's manual and were incorporated in training to standardize student familiarization procedures.

3. Symbology Interpretation as an Enabling Skill. ANG pilots required substantially improved training in HUD/radar interpretation skills as a lead-in to the AIT phase. Lack of these

enabling skills caused AIT training to be much less efficient than it should have been during the first several classes. This led to revision of the training syllabus to provide more AIT time for basic skills development and eventually led to the development of special purpose computer-based training materials.

A PC-based test was developed by AL/HRA which permitted measurement of HUD/radar symbology interpretation skills. The test also provided a means to determine when a student had acquired a sufficient level of skill to begin AIT training. For the first several classes, results of testing showed generally low interpretational skills both before and after AIT training.

As a result, a drill-and-practice program was developed and added to the test to aid pilot acquisition of symbology skills prior to AIT training. This program substantially improved the efficiency of AIT training.

4. Lack of Visual Display. The prototype AIT was not equipped with a forward view, out-of-the-cockpit, visual display. While the initial reaction of ANG student pilots to this limitation was negative, training effects were positive. The resulting "forced" reliance on HUD/radar information during training produced substantial skill gains in intercept geometry and situational awareness, as reported by instructor pilots.

At first, many pilots reported feeling uncomfortable with having to "fly" the device based only on information from the HUD/radar displays. However, with additional practice, pilots found little difficulty controlling simulated flight in the AIT. Instructors reported the HUD/radar skills thus acquired developed rapidly and transferred effectively during aircraft training.

5. Fidelity Limitations. ANG pilots found the lack of pilot-controllable, simulated flight of the trainer unacceptable. As a result, AL/HRA promptly developed and retrofitted enhanced software to provide acceptable flight controls. Device training utility and pilot acceptance clearly increased following this upgrade. The resulting lesson for AL/HRA was that any aircraft capabilities included in the simulation must be functionally equivalent to the aircraft. Or, if present in the device, they must be of such obviously low fidelity that pilots are not led to equate trainer capabilities with those of the aircraft.

6. Intercept Performance Measurement. Assessment of pilot performance of intercepts was better accomplished using well-developed debriefing feedback techniques rather than a computer-scoring approach. The development of a linear scoring system which

assigned weighted values for various intercept components proved inadequate for purposes of training evaluation.

As a result of this lesson, subsequent approaches to performance evaluation during AIT training have emphasized methods to improve the feedback to the pilot by providing enhanced graphic representations of intercepts to support debriefing activities following training. A subsequent evaluation of AIT training effectiveness employed ratings of intercept performance by expert pilots rather than the computerized model.

7. **Training Effectiveness: Empirical Data. Findings from an initial AIT empirical evaluation were inconclusive relative to AIT training effectiveness.**

In addition to opinion data collected from instructors and students after the prototype device was installed at the squadron, AL/HRA conducted an experimental study to assess the transfer effectiveness of AIT training to the F-16 simulator. Problems in experimental design and methods were judged to be responsible for inconclusive results. Lessons learned from this study were applied to improve a subsequent training effectiveness evaluation of the AIT.

8. **Prototyping Methodology. The development and delivery of timely, yet state-of-the-art training technology directly from AL/HRA to the user presented a dilemma. The prototyping process had to accommodate timely infusion of new technology, otherwise, the trainer would be obsolete upon delivery. However, if technology infusion dominated development, the effort would become consumed "chasing" technology so that a usable device would never be delivered. A balance was reached by developing a two-step prototyping approach which made possible timely infusion of technology into the trainer design. A first-stage device was used for engineering development to work out problems with new technology; a second-stage device was used by pilots to test software changes and to determine when design changes were mature enough to be fielded.**

Lessons Learned from the ACC Schoolhouse Experience

AL/HRA researchers installed an upgraded version of the AIT at the 58th Tactical Training Squadron, Luke AFB approximately two years following its introduction at the ANG, Tucson. The AIT delivered to the Luke schoolhouse incorporated substantially more training capabilities than the original ANG version. Enhancements included instructor-configurable training scenarios, improved aerodynamics and handling characteristics, and the outside-the-cockpit visual display previously described. The trainer was integrated into the initial qualification training course for F-16 pilots. The B-Course (for pilots coming directly from undergraduate pilot training) was modified to incorporate the AIT as an experimental adjunct to the syllabus. AL/HRA monitored usage and management of the AIT in the B-course for about two years and collected data to evaluate training device effectiveness.

1. Utility and Training Effectiveness. The AIT was well accepted in the schoolhouse community as an introductory level, air-to-air training device. It filled an important training need in the course. The effectiveness of the AIT and its acceptance in the schoolhouse were the result of extensive training analysis and design, technology development, and long-term efforts to improve device training qualities, including the application of lessons learned from experience with the ANG.

The training analysis and design was a long-term effort that also successfully incorporated the use of subject-matter experts (SMEs) as consultants in the development and transition process. The product evaluation involved extensive observation of training activities, assessment of pilot opinion, and collection of training data in the squadron. A formal evaluation of the AIT in the B-course demonstrated the training effectiveness of the trainer.

2. Self-Paced Training Capability. Student pilots were able to successfully use the training menus, instructional features, and practice scenarios without the assistance of an instructor pilot. Students generally preferred the self-paced mode of training on the AIT as a means toward developing intercept skills. Instructors also accepted the self-paced mode of use.

3. Instructor Acceptance. Instructor pilots accepted the AIT as a useful training resource. This was attributable to the AIT's training software capabilities, compatibility with syllabus objectives and content, and the convenience to students afforded by the presence of the AIT in the academic squadron.

4. Adoption of the Trainer. Data from the schoolhouse evaluation, both from user opinion and empirical training data, pointed clearly to the effectiveness of the AIT and the need for adoption into the syllabus. However, the decision to implement the trainer formally was delayed with the result that the second schoolhouse (MacDill AFB, FL) did not receive training benefits from the AIT for some two years following completion of the empirical study at Luke. Stronger advocacy of the AIT by AL/HRA might have accelerated acquisition of the second schoolhouse device.

Lessons Learned from the AFRES Experience

As a logical outcome of the considerable success of the AIT in the ANG and ACC schoolhouses, an attempt was made to use AITs in the operational F-16 squadrons of the Air Force Reserve. Trainers were upgraded to include more sophisticated targeting capabilities and training scenarios. Two AITs were networked together so that pilots could simulate two-ship operations. AITs were installed at several AFRES squadrons over a period of about two years for evaluation of training utility. The following items summarize the lessons learned from use of the trainers in the AFRES squadrons.

1. <u>Trainer Utility for Operational Pilots</u>. For experienced F-16 pilots in the AFRES operational squadrons, the training utility of the AIT was limited. Even with enhancements in the capabilities of the trainer, pilots in these squadrons were able to realize relatively minor training benefits from the AIT such as basic switchology skill refreshment.

2. <u>Basic Skill Refreshment Value</u>. The training utility of the AIT for switchology skill maintenance corresponded with pilot experience.

Less experienced operational pilots derived some benefit from the AIT for switchology skill refresh. Therefore, units with relatively large numbers of less experienced pilots benefitted somewhat more from the AITs than did squadrons with proportionately higher numbers of pilots with more experience.

3. <u>Fidelity</u>. Limitations in AIT fidelity and training capabilities which were acceptable in the schoolhouse were found to be unacceptable to operational pilots in AFRES units, particularly in units where pilot experience was high. Data collected in these squadrons showed that once a pilot had accrued about 300 hours in the jet, the value of AIT training became negligible.

Fidelity was a factor in keeping the cost of the AIT to acceptable level. Shortcomings in some aspects of AIT flight control fidelity were of minor consequence in learning basic skills and intercept concepts. However, these proved to be distracting to experienced pilots. Design of intercept scenarios and the limited capabilities of computerized targets proved to be unchallenging to AFRES pilots and therefore basically unacceptable for training purposes.

4. <u>Design Enhancements</u>. To support AFRES F-16 operational unit training, required device capabilities extended well beyond those of the AIT. In view of the results obtained using the AIT in

AFRES, the magnitude required changes, and their associated costs, the reasonable choice would be to design a new device, rather than attempting extensive modification of the AIT.

The two major areas of device enhancement would be in simulation fidelity and training capability. Device fidelity development would include aircraft aerodynamics, engines, cockpit environment (for relevant controls and displays), radar, HUD, and relevant weapons. Major areas of training capability development include target maneuvering capabilities to levels which challenge the knowledge and skill of experienced pilots.

5. <u>Use of Two-Ship Mode</u>. Although the networking capability of two AITs for two-ship operations was developed as a training enhancement for the AFRES squadrons, pilots in these units made little use of the two-ship feature. Related to this finding was the fact that pilots preferred to use the AIT in a "solo" mode. Pilots also reported having technical problems using the two-ship mode.

It had been originally hoped that the addition of the "networked" AIT cockpits would compensate for other training limitations and that pilots would be motivated to use it extensively. However, this turned out not to be the case.

6. <u>Trainer Reliability and Technical Service</u>. Better technical service to users, particularly during the initial period of use at the unit, could have alleviated trainer reliability problems and promoted better user acceptance of AITs in the squadrons. This was especially true for the first AFRES squadrons who received the AITs. The operational reliability of original AIT had been exemplary. However, as the trainer evolved and its complexity increased, so did reliability problems. By the time the AITs were fielded to AFRES units, reliability problems had become considerable and required special attention.

Analysis of AIT repair/maintenance procedures revealed that two relatively simple changes would improve service to the field: (a) provide a single point of contact for maintenance for each field user and (b) provide more frequent contact with field users.

7. <u>Technology Transition</u>. Fully transitioning the prototype AIT from the laboratory to the user/manufacturer was not possible because of inability to assume responsibilities for software development, upgrades, and maintenance. As a result technology transition was incomplete; AL/HRA had to retain responsibility for software development and maintenance.

8. ANG F-16 Conversion Training. ANG squadrons converting to the F-16 found the AIT advantageous as a familiarization device in squadrons and as part of the conversion course syllabus at the schoolhouse. Some of the AFRES units relinquished their AITs for use by ANG units.

LESSONS LEARNED FROM THE ANG EXPERIENCE: ELABORATION

1. ANG User Acceptance and Training Evaluation Results

Both students and instructors accepted and used the AIT enthusiastically as an addition the F-16 conversion course. Early limitations in prototype capabilities were corrected and the AIT was successfully integrated into the course syllabus..

Laboratory observers spent considerable time observing AIT training activities and interviewing instructors, students, and managers. The data collected from these activities provided initial evidence of the high level of training utility and the high level of acceptance of the AIT by pilots. Observations extended over a period of several months and involved several conversion classes. Specific data from questionnaires included the amounts and types of training accomplished by individuals on the AIT, use of instructional features by both students and instructors, instructors' procedures and techniques, instructor and student acceptance of device features and capabilities, requirements for software and hardware revisions, and device reliability. Findings were also used to improve device capabilities.

The study of how pilots used the instructional features of the device revealed that most instructional features such as the freeze and scenario replay were valuable training capabilities. The instructional capabilities and training scenarios were accessible through menu options which pilots found easy to use.

The graphic representation modes proved to be particularly valuable. As visual representations of the intercept designed to supplement corresponding information on HUD and radar displays, these graphics were effective in aiding pilots to understand intercept geometry. Instructors reported they were very valuable in aiding students to better "visualize" the spatial-temporal aspects of intercepts. These instructional displays required few refinements and continued to be one of the most effective aspects of AIT training.

The second part of the evaluation of AIT training at the ANG involved the participation of student pilots in an experiment to determine the effectiveness of transfer of training from the AIT to an F-16 simulator. The objective was to determine if training in the AIT would provide an advantage to students entering the simulator phase of conversion training. Several groups of student pilots were trained using variations of AIT training. One group of pilots received no AIT training and served as a control group. A computer-algorithm was used to score pilot performance on a series of intercepts flown in the simulator as a transfer of training test. All pilots who participated received the same simulator performance test.

Results showed that pilots who received the highest amount of AIT training tended to achieve higher scores in the simulator. However, methodological problems with this study preclude conclusive statements based upon the obtained data. Problems included the relatively small number of pilots assigned to experimental groups, the large number of instructors used in the experimental training and the method of their involvement, the method of scoring, group differences contributing to a significant class by group interaction, and questionable use of pilots with knowledge of intercept as subject participants in the study. A complete report of this study is contained in Lahey, Hubbard, and Edwards (1987).

However, shortcomings of the empirical study aside, the evaluation effort did permit the observation of the practical training benefits from the AIT for the ANG. Opinions from both students and instructors clearly indicated a high rate of device usage and acceptance in the squadron.

Useful information accrued during the installation and "shakedown" of the AIT at the ANG. Working through the training process with users, observing usage patterns, sampling pilot opinion, and observing training methods, all contributed to the laboratory's experience and to technology transition. Collectively, these experiences were valuable for purposes of refining the laboratory training device and improving the evaluation process.

2. Familiarization Training.

The development of effective training for student pilots was to some extent a collaboration between instructors at the 162nd TS and software developers at AL/HRA. Despite all of the attempts to make the AIT operational manual easy to use, it was found that most students needed time to accommodate to the trainer. This involved becoming comfortable with the initialization procedures and gaining facility with instructional features and menus. In addition, many students found that HUD and radar symbology interpretation skill required more time than had been anticipated. This aspect of training is discussed in detail in #3 below.

3. Symbology Interpretation as an Enabling Skill.

An early assumption by those developing the F-16 training syllabus at the 162nd TS was that student pilots would be able to learn basic radar interpretation and switchology skills during academics prior to spending time on the AIT. This assumption included the belief that with a suitable level of these basic skills, students would be able to use the AIT to integrate the switchology with intercept procedures and then devote considerable time to practicing whole intercepts using the various scenarios available. Training time allocations in the initial version of the syllabus reflected these assumptions.

Experience with the first several classes indicated otherwise. Academics training including media materials provided insufficient training to produce transferrable hands-on stick and throttle skills. As a result, instructors found students spending large amounts of their AIT time working on basic skills. This left inadequate time to integrate skills and practice intercepts. Syllabus changes were required to provide additional AIT training.

Instructors were persistent in the view that the AIT should be used predominantly for whole-task intercept practice, rather than for the subskills. As a result, another training program was developed which students could operate off-line on a personal computer (Lahey & Anselm, 1989). This program, which became known as the HUD/REO Trainer, provided a means of systematically assessing pilot readiness for AIT training and thus increased training efficiency. The HUD/REO became a standard part of the revised conversion course syllabus.

4. Lack of Visual Display.

From a strict training perspective, the lack of the visual display proved beneficial because pilots had to rely on cockpit information in order to "fly" the simulated aircraft. In this regard, the AIT was not intended to teach pilots F-16 handling qualities. In the final analysis, the lack of the visual display turned out to be more a device acceptance issue rather than a training effectiveness issue.

As a postscript, within two years following introduction of the AIT, the lack of the outside visual scene was corrected when a dramatic price reduction of graphics work stations made the addition of the display an affordable upgrade for the trainer. AITs produced following the price reduction were equipped with an "outside" visual display capability. Most existing AITs were also retrofitted.

5. Fidelity Limitations.

The original prototype was not equipped with real-time, fully pilot-controllable flight. The pilot was able to control only segmented portions of intercepts interspersed with "freeze" of flight for instructional purposes. In the initial trainer a computerized model of the correct intercept controlled the trainers flight following radar lock-on, so that the pilot was, in effect, "along for the ride" only. A fully "flyable" version of trainer software was under development, but was not available for the first several conversion course classes. Some pilots who participated in the initial training effectiveness evaluation did receive some training using the fully flyable software model. In response to pilot perceptions of this limitation, AL/HRA accelerated work on the flyable software and the trainer was upgraded within about seven months after the initial receipt of the trainer at the squadron.

Following the flyable model upgrade, pilots reported deficiencies in the aerodynamics and engine models software. The chief complaint about aerodynamics was a perceived distortion of the elapsed time of intercepts. Many indicated that the time required in the AIT to complete an intercept seemed less than that required in the real aircraft for the same intercept. Another frequent complaint was the perception that the trainer stick control was too sensitive relative to the aircraft, resulting in a tendency to overcontrol pitch and roll during intercept training.

Part of this lesson learned resulted from the required improvements in AIT fidelity. In a part-task device, fidelity of essential training capabilities is paramount. If a capability is required for training, high fidelity simulation of that function is essential. Project engineers came to refer to this concept as selective fidelity. Any function simulated must be functionally equivalent to the aircraft. Inexperienced pilots may be less critical of fidelity compared to experienced pilots, but unmet pilot expectations can jeopardize device acceptance and project success. Inadequate fidelity raises the fear of negative training and as such, is always a concern.

The fidelity of the AIT prototype was deficient in several critical areas and required immediate software upgrades to meet training requirements. However, from the outset, pilot expectations of the AIT's training capabilities were tempered by the fact that the appearance of the AIT was quite abstract (it did not look like a cockpit). Once the needed upgrades were installed, training utility and pilot acceptance of the AIT in the squadron were essentially achieved.

6. Intercept Performance Measurement.

Background on the Original Scoring Algorithm. Intercept performance in the original linear model was measured against a parametric model of an idealized intercept. Flight data during each intercept attempted by the pilot were captured which included 30 measures of conformance to idealized intercept flight parameters. Scores assigned for each measure were summed to provide a single numerical score for the intercept. The pilot could earn a maximum of 1,000 points per intercept. Penalties for errors such as out-maneuvering or "gimballing" the radar, breaking radar lock, negative overtake during conversion, failure to uncage the missile prior to launch, and excessive time to complete the intercept resulted in points subtracted from the total score. Thus, negative scores on intercepts were possible and were in fact observed in several instances.

The numerical weighting of intercept components was found to be problematic for several reasons: (a) experts may not agree on what constitutes the "best" intercept, making consensus on scoring difficult; (b) standards of performance may vary across squadrons based upon such factors as rules of engagement (ROE) and directed operational capability (DOC); (c) numerical scores alone may not provide sufficiently specific feedback to help pilots improve performance; and (d) pilots may resist being scored by computer.

In the present case, the rationale for selecting and weighting performance components was not subjected to sufficient review by experts. This resulted in the assignment of inordinate weights to some factors. For example, the penalty for gimballing the radar was minus 400 points from the 1,000 point total. This turned out to be too heavy a penalty for this factor and resulted in severely skewed scores for a number of pilots.

Results from Findings. This lesson learned combined with a number of years experience in dealing with measurement of complex pilot performance led to concerted efforts to develop feedback techniques to aid pilots obtain accurate representations of performance. This more recent approach is based on the assumption that if pilots are provided sufficiently clear and complete feedback on their performance, they are likely to identify mistakes and make corrections themselves, or in consultation with experts. Exploiting computer capabilities to support this approach for air intercept training has been reasonably successful in the case of the AIT.

Enhanced debriefing capabilities as AIT training features have been developed and used successfully.

7. <u>Training Effectiveness: Empirical Data</u>.

Obtaining reliable evidence of the training effectiveness of the AIT required concerted effort to ensure a suitable experimental design methodology for field testing of the device. While the initial training effectiveness evaluation produced inconclusive data, lessons learned from that effort were applied to a subsequent device training evaluation. Data collection for the second evaluation required more than a year, but resulted in clear evidence of the AIT's training utility and effectiveness.

8. <u>Prototyping Methodology</u>.

The approach taken by AL/HRA was to get ahead of the "game" by designing, as it were, with "future" technology. The VME-1000, a 68020-based system, was selected. At the time, this microcomputer design was so new it was still in an unrefined state from the manufacturer. This system was selected largely on the merits of its potential to accommodate long-term future growth and flexibility for configuration changes. The penalty paid was in working through some system flaws and needed refinements jointly with the manufacturer.

What evolved from this lesson learned was a two-phase prototyping process. A first-stage device was used as an engineering test-bed for smoothing the "ragged edge" of "green" technology. A second prototype was used for the actual product development. This made short-term "freezes" of the trainer design acceptable to engineers who could rely on the first-stage device. Knowledge gained from experimentation using the first-stage device gave engineers a flexible tool to determine when new technology was ready for insertion into the (second-stage) product. The process outcome was as intended: the user received the latest technology on a timely basis.

Another aspect of the prototyping process involved SMEs. As the AIT program grew, users multiplied. Rather than going to various user squadrons to test changes and correct system problems, it became more efficient to invite pilots from several units to AL/HRA to test innovations. Using this approach, it was sometimes possible to eliminate problems before exporting the changes to users. This aspect of the prototyping lesson learned became an engineering benchmark and is now standard practice for training device development at AL/HRA.

LESSONS LEARNED FROM THE ACC SCHOOLHOUSE EXPERIENCE: ELABORATION

As mentioned earlier, the ACC schoolhouse trainer contained several enhancements beyond the original prototype. As in the original trainer, menu access to training scenarios provided students with ordered levels of task complexity and challenge. In the upgraded schoolhouse trainer, the type and number of intercept scenarios was expanded to support training in the basic areas of radar employment, multiple target sorting, and intercept geometry. The enhanced scenarios provided the instructor options to manipulate the number and configuration of radar targets via the student instructor control station (SICS).

1. Utility and Training Effectiveness

As it had been with the original AIT, the AL/HRA intent during the ACC schoolhouse phase was to make a systematic study of device acceptance and training utility. During the schoolhouse phase, questionnaires, interviews, and a formal training experiment were conducted in the squadron to collect evidence of device acceptance, utility, and training effectiveness.

Student Opinion. Two questionnaires were distributed to students enrolled in the B-Course. Students were asked a variety of questions about the capabilities of the AIT and their use of the device. A third questionnaire was circulated to students enrolled in the B-course at the 56th Training Squadron at MacDill AFB, FL following the delivery of an AIT for that ACC schoolhouse, about two years following the advent of the AIT at the Luke squadron. A summary of student pilot opinion from these questionnaires, relative to trainer effectiveness follows.

a. AIT acceptance and training effectiveness at the schoolhouse was based upon lessons learned from the ANG experience. A considerable number of additional capabilities and refinements were completed by the time the AIT arrived for evaluation at the ACC schoolhouse. With few exceptions, the instructional features and training capabilities developed at the ANG served well in the B-course.

b. All the training features in the AIT were employed by B-course students, some more than others. However, none of the training features were used by less than 25% of students. The soundness of the training analysis and design underlying these features was confirmed by the response of students. Of all the features embodied in the trainer, perhaps the most successful, judging by usage data, were the ancillary graphics displays on the SICS used to convey intercept geometry.

In responding to questionnaires, pilots indicated the AIT aided their development of skills in the following specific areas: general radar employment, target sorting and management, intercept geometry, situational awareness, and overall execution of intercepts.

Students reported the AIT provided an effective "bridge" between classroom instruction and "hands-on" system training.

Students indicated they found instructional capabilities reasonably "user friendly."

c. AIT intercept training, as an adjunct to the conventional syllabus, was relevant and timely, and highly accepted. Students responded to the AIT as an opportunity to operationalize concepts introduced in academics classes. They reported that what they had learned in class became immediately relevant via the AIT. The convenience of having the AIT present in the squadron facilitated learning.

d. In responding the questionnaire items related to trainer fidelity, pilots indicated general agreement that basic avionics functions of the trainer (master radar modes, weapons switchology, HUD functions, and overall trainer performance) performed well referenced to the aircraft. There was less agreement about the accuracy of flight controls. Pilots' reservations about the control sensitivity seemed to carry-over from those of pilots in the ANG. But the control sensitivity shortcoming was not shown to be detrimental to device training effectiveness. Both students and instructors would have appreciated improved control fidelity as well as the availability of targets with more sophisticated capabilities. But these improvements were beyond the level of fidelity required to support syllabus requirements and would have been too expensive to justify their addition.

e. While the essential design of training software was effective, considerable time was required for pilots to learn the basic operation of the device. A number of pilots had trouble getting the trainer up and operating. This problem had not been fully resolved by the end of the period of schoolhouse evaluation.

Training Effectiveness Evaluation. A formal training experiment, by AL/HRA, was conducted using B-course students as subjects to test the training effectiveness of the AIT. Lessons learned from an earlier training effectiveness evaluation, conducted at ANG, Tucson were applied to improve experimental methodology. Fifty student pilots across several B-Course classes participated. The experiment involved two groups of students, 25 in each group. As a part of academics training on intercepts, one group received training on the AIT, the other group received no AIT training. Following the experimental training, all students in both groups were tested on their ability to perform air intercepts in the operational flight trainer (F-16 simulator) as a means to test transfer effects.

Results from this experiment are summarized as follows: Relative to the non-AIT trained group, the AIT-trained group (a) achieved higher proficiency ratings in four or five basic skill areas, (b) achieved performance proficiency in significantly greater numbers and on significantly more types of intercepts, (c) were able to fly significantly more advanced intercepts during the simulator training, and (d) on advanced intercepts, a significantly higher percentage of AIT-trained pilots reached acceptable levels of proficiency. A complete report of this study is contained in Edwards and Hubbard, 1991.

Thus, data from both pilots opinion surveys and the formal training experiment clearly substantiated the utility and effectiveness of AIT training in the B-course.

2. Self-Paced Training Capability. Provision for self-paced training was a design issue during development of the AIT. Typically, simulators require the presence of an instructor during training activities. The AIT, although a part-task trainer, was partially an aircraft simulator. Training capabilities were an integral part of trainer software. The design issue was one of training efficiency. If the device could be used successfully in the self-paced mode by the student, substantial instructor time could be saved during the course. Related questions were raised. Would students be motivated to use the trainer by themselves? Would training be effective without an instructor? Would instructors view self-pacing as a help or hindrance in the course?

The results of evaluation showed that after sufficient familiarization with the AIT, most students came to prefer the self-paced mode training. They were able to use the training menus and features independently of the instructor. The most frequently mentioned comment from students was that they liked the self-paced mode because of the independence it afforded them. Typical comments were, "There are a lot of things you need to learn on your own in the AIT," and "We need to do it our own way; that works best." Moreover, students took advantage of the presence of the trainer in the squadron which added convenience and flexibility to training schedules.

Relative to instructors, when they became convinced of the capabilities of the AIT, and with the ability of students to use the device alone successfully, there were no reservations about self-paced usage. Indeed, instructors came to regard the AIT as a valuable asset which allowed them to reapportion instructional time to other training areas. However, this acceptance came only after instructors had personally observed and evaluated student use of the AIT and "reconciled" the "solo" capability with the existing "ways of doing things" at the schoolhouse.

3. Instructor Acceptance. During the introduction of the AIT at the schoolhouse, instructors from both academics and the flight line used the AIT and participated in its evaluation. The reactions of instructors were viewed as critical to the successful implementation of the AIT in the squadron. For academics instructors, understanding of the AIT was more extensive because most of them spent considerable time with students on the device.

A few of the instructors had also been consulted by AL/HRA during the design of AIT training software. Instructors were interviewed about AIT capabilities and how they used it for training.

At first, the general attitude of instructors toward the trainer was one of mild skepticism. Several other part-task devices had preceded the AIT in the squadron. These trainers had been only "tolerated" because they added some training value, but left much to be desired as effective and reliable training equipment. So, for the AIT, instructors seemed to adopt a "wait and see" attitude. However, by the end of the training evaluation period, collective instructor opinion was highly favorable, in spite of several areas of needed improvement identified by instructors. A summary of instructor opinion about the AIT, compiled from interview data, appears below.

Training Capability. Probably the most often-mentioned training benefit identified by instructors was that it provided students with what is sometimes referred to as the "big picture." All instructors interviewed perceived the AIT as aiding students to develop a facility to "move" mentally between two-dimensional information (e.g., cockpit displays) and a concept of relationships between two or more aircraft maneuvering in the real (three-dimensional) environment. Instructors indicated that a grasp of this dynamic "geometry" is perhaps the single most important concept during the air-to-air phase of the course. Instructors noted that students using the AIT seemed to grasp spatial/temporal concepts more quickly than non-AIT trained students.

Instructional Content. There was general agreement among instructors that the content and structure of training scenarios was appropriate for the B-Course. This acceptance was related to the method by which scenarios were designed by AL/HRA. Conceptualization and development of scenarios was accomplished by instructional designers and involved extensive consultation with subject-matter experts over an extended time period. In several cases, instructors from the F-16 training community had consulted with the designer on instructional content. Some instructors were also aware of the implementation of the original device at Tucson. Thus by the time the trainer arrived on site at the Luke AFB schoolhouse, its instructional capabilities had been subjected to critique by various pilots. One aspect of this lesson learned, therefore, underscored the importance of involving expert users early in device design and continuing consultation during evaluation.

Availability of Practice Time. Instructors regarded the capability to practice intercepts afforded by the AIT as very important during academics. The B-course syllabus provided only three simulator sorties and three aircraft sorties which contained substantial time devoted to air intercepts. By contrast, the AIT afforded a relative abundance of time to students to work out an understanding of intercepts and to acquire transferrable skills for simulator and aircraft training. In this regard, instructors also said they found the fidelity of the AIT sufficiently accurate for training transfer. They regarded fidelity as critical to skill transfer in that when students worked out an idea or technique using the AIT, they could be confident that it would work the same way in the aircraft.

A goal of AIT design was available, affordable training in the squadron for specific basic skills. This goal was successfully met. Class size averaged 13 or 14 students during the evaluation period. Student scheduling of the trainer turned out to be workable, in spite of a few "bottlenecks." Instructors noted that some of the more motivated students would come in on weekends to use the AIT. The availability of the device seven days per week helped because it provided maximum flexibility for students to arrange schedules. While the AIT did add training time to the syllabus, its accessibility to students in the squadron helped offset the need for additional training time.

Skill Integration. Another prominently-mentioned training quality was the capability to "work different skills together" or to integrate skills. One example is gaining facility with throttle and stick switches when identifying and sorting multiple targets on the radar screen. Instructors viewed this aspect of training as being a unique advantage afforded by the AIT, and one particularly useful in preparing students to spend time productively in the simulator.

Needed Improvements. All of the instructors indicated they experienced some difficulty learning to control flight on the AIT. The stick seemed oversensitive causing overcontrol of pitch and roll inputs. Some instructors found that the trainer was not able to accelerate like the aircraft, another aspect of flight fidelity. They also found need for improvement with the target capabilities of various intercept scenarios. Most indicated targets were too slow generally and some said targets should be able to maneuver, at least to some degree. Several instructors said the pilot should be more easily able to "get out" of (disengage) the multiship intercept scenarios. These findings were used as inputs to improve the fidelity and functional capabilities of the AIT in the schoolhouse.

4. Adoption of the Trainer. Following the initial positive evaluation of the AIT by instructors and students at the Luke schoolhouse, the hope of the 4444th Operations Squadron, Detachment 1 was that its formal adoption into the B-Course syllabus would be expeditious. However, the syllabus could not be formally revised until the other F-16 schoolhouse at MacDill AFB (56th TS) also received an AIT.

ACC had accepted the AIT as a testbed device by memorandum of agreement as a quid pro quo for AL/HRA research privileges at the schoolhouse. No funds were solicited nor received by AL/HRA from ACC for the trainer. The response to the trainer at Luke had been very favorable and subsequent empirical data from the formal training effectiveness evaluation clearly demonstrated benefits of the device in the B-course. However, this evidence appeared to be misunderstood or ignored by Headquarters ACC/DOT. While the laboratory continued to support the O&M costs of the AIT in the schoolhouse at no cost to ACC, the reasonable expectation was that a second device would be provided for the MacDill schoolhouse in a timely manner. However, HQ ACC questioned the presence of the AIT in the schoolhouse. Two issues were raised by ACC/DOT: (a) the need for a specialized trainer for air-to-air training was questioned because the F-16 role was primarily air-to-ground, implying that emphasis on training resources should be deferred to the latter role; and (b) since the schoolhouse had successfully met training requirements before the AIT, its addition to the B-course was unjustified by requirements. Notwithstanding the terms of the memorandum of agreement between ACC and AL/HRA, HQ ACC seemed to regard the AIT as an unsolicited addition to the course. Thus, the logical inference from these objections was that HQ ACC saw the AIT merely as a "nice-to-have" device. Fortunately, Training Systems Center at Luke AFB had begun to produce AITs in quantity and was able to acquire sufficient spare hardware components to assemble a second schoolhouse device. Because the costs of trainer software development had been paid by AL/HRA, the cost of the second device was only for hardware. At length, 4444th, Det 1 was able to convince headquarters that the training value of the AIT was, indeed, worth the cost of the hardware. The second device was assembled and delivered to the MacDill AFB schoolhouse in late 1991, some two years after the completion of the training effectiveness evaluation at Luke.

LESSONS LEARNED FROM THE AFRES EXPERIENCE: ELABORATION

With the notable success of the AIT in the schoolhouse, consideration of extended applications seemed logical. One possibility was modification of the trainer for operational users, particularly the Air Force Reserve units flying F-16 aircraft. The only ground-based trainers available in the Reserve during the late 1980s were several older F-16A simulators which were regarded of marginal value because of limited visual capabilities, poor reliability, high operations and maintenance (O&M) costs and limited availability for use by reservists. These factors led to a decision by the Reserve to phase out the trainers. By 1990, for example, the 466th Fighter Squadron (FS), Hill AFB, UT no longer had a simulator available. The 302nd FS, Luke AFB had only limited access to a simulator, the F-16 operational flight trainer (OFT), because of the priority for that device in the F-16 schoolhouse.

The primary AFRES interest in ground-based training equipment was in three areas considered critical to maintenance of safety of flight standards, particularly for reservist pilots: (1) emergency procedures, (2) instrument landings, and (3) air-to-air operations. Skill maintenance was of considerable interest because of the large number of pilots in reserve units who spend frequent, extended periods of time away from the F-16. Although the AIT offered training capabilities for only limited aspects of air-to-air training, it was viewed by Reserve management as promising technology with several virtues: (a) low cost, (b) timely availability compared to conventional acquisition, and (c) design flexibility with expansion potential for other training functions.

The AFRES decision to pursue AIT enhancement was a technology investment strategy approach. As a means of providing a first look at training feasibility, the 302nd FS at Luke AFB was selected to try out the AIT. AL/HRA had been developing the ability to network two AITs for two-ship training for about a year when the first two-ship AIT configuration was delivered to the 302nd for evaluation. Training software in the device was approximately the same as contained in the schoolhouse version. Operational pilots experimented with the device for about four months during the latter half of 1988.

During this trial period, it became clear that the software setups as designed for the schoolhouse were largely inappropriate for use by operational pilots. The experienced pilots were well beyond being able to benefit from basic intercept maneuver scenarios, even in a multiship mode. The determination of how training scenarios should be upgraded was the subject of considerable study by laboratory personnel in consultation with AFRES subject matter experts. Required training enhancements identified were as follows:

1. Improved adversary engagement scenarios in the two-ship (networked mode) versus 1,2,4, and 6 computer controlled targets.

2. Improved fidelity in the aerodynamic performance of the trainer.

3. Improved fidelity of radar simulation and targeting.

4. Capability to engage maneuvering targets with a higher degree of realism.

The organization of scenarios for the schoolhouse was also found to be cumbersome for operational pilots. They wanted quick access to advanced complexity scenarios without the need to "branch" through a hierarchy of other scenarios. In addition, AFRES needed scenarios of considerably greater combat complexity, and also a capability for the squadron weapons system officer to manipulate scenario content to meet various situational requirements for unit training purposes.

As a result of findings from the trial period, AL/HRA developers attempted to provide enhancements acceptable to AFRES. As will be seen, both fidelity and training scenario enhancements proved to be substantial challenges.

Although the identified enhancements were still under development, AFRES decided to pursue an expanded use of the AIT employing the hardware assembly capabilities of the Training Systems Center at Luke AFB. The basic arrangement was that AL/HRA would continue to develop software for the trainer while TSC would assume the job of assembling a number of AITs for AFRES and other customers. As software enhancements were completed, they would be "exported" to device users. The primary interest of the laboratory would be in developing effective software; the primary interest of TSC would be in hardware assembly and device maintenance for field users. Under this arrangement, AFRES began deploying AITs to F-16 operational units. These units included the 466th FS, Hill AFB, UT; the 89th FS, Wright-Patterson AFB, OH; the 465th FS, Tinker AFB, OK; and the 704th FS, Bergstrom AFB, TX. AFRES units located at Carswell AFB, TX and Homestead AFB, FL used the AITs for short periods of time but did not retain the devices.

During the period of deployment, user surveys and interviews with pilots were conducted by AL/HRA. These data collection activities spanned a period of about two years and involved the participation of 53 pilots who responded to questionnaires and interviews at various units.

Users responded to questions covering a variety of aspects of training using the AITs. These areas included the type, extent and patterns of use, preferred modes of use, training features and capabilities, problems encountered while using the device, pilot assessment of various aspects of device fidelity, perceived need for improvements, perceived needed improvements in device management, most and least liked aspects of AIT training, and general comments about the AIT.

1. Trainer Utility for Operational Pilots.

Device Usage. Pilots reported using the AIT an average of about 3.5 times per month. Usage patterns varied considerably across units and by pilot experience and time in the unit.

Preferred Mode of Use. Pilots indicated that 85% of the time they used the AIT alone, rather than in the two-ship mode with other pilots. This finding was disappointing in that the purpose of developing the network mode was to permit these pilots to simulate two-ship operations. Interview data showed that pilots preferred independent use of the device largely as a matter of convenience and also because many seemed to feel the benefits of the two-ship mode were marginal compared to the effort required to coordinate schedules of other pilots. Another problem was device reliability. Some pilots candidly stated that the value of the two-ship mode did not justify the time and difficulty getting the system to work reliably.

Use of Scenarios. Virtually all pilots reported using the multiple target scenarios. These were the most complex available in the AIT and it was clear that for operational pilots, these "high end" scenarios were the only ones of interest. The operational pilot, as it turned out, challenged the capabilities of the AIT to the utmost. Many pilots indicated that they needed much more capability in the computerized targets.

Trainer Fidelity. Pilots rated the fidelity characteristics of the AIT well below the ratings given by student and instructor pilots in the schoolhouse.

Needed Improvements. The major areas of needed improvement indicated by pilots (in order of magnitude) were:

1. Improved aircraft aerodynamics, controls, and avionics.

2. Improved target maneuvering capabilities.

3. Improved multiship capabilities and operation.

4. Added and improved weapons capabilities.

Training Value of AIT. Pilots were asked to rate the value of AIT training in the worth of their own time and the impact of AIT training on unit readiness. Responses showed that while pilots were not totally negative toward the AIT, they perceived its value to be limited by fidelity and training capabilities.

Check Ride Innovation. Of the AFRES squadron using the AIT, the 89th FS seemed to derive somewhat more training value from the device. This was primarily because the majority of pilots were relatively new to the F-16. The unit training officer indicated they used the AIT to augment portions of the annual air-to-air tactics check ride required for all pilots. The requirement for AIT training was in addition to the aircraft ride itself. Pilots used the AIT to sharpen basic skills prior to the check ride. They were allowed the option of selecting any of the 2v-maneuvering multitarget scenarios for their check ride rehearsal. This use of the AIT appeared to be a significant training innovation in this squadron.

2. Basic Skill Refresher Value. The value of the AIT for refresh training among less experienced reservist pilots was best illustrated at the 89th FS. Many of these pilots who had

experience levels of from 80 to 150 hours in the F-16 spent considerably more time using the AIT than pilots in other AFRES units. Substantial amounts of their training in the device were devoted to basic skill refresh training. The weapons system officer indicated that a number of the newer pilots came to the squadron "on their own time" for the express purpose of using the AIT. Questionnaire data also showed that 89th FS pilots tended to rate the value of AIT training considerably higher than pilots with more experience in other units. In contrast to this unit, pilot experience at the 466th FS, Hill AFB averaged over 700 hours per pilot. Only a few pilots in the 466th had fewer than 200 hours in the aircraft. The use of the AIT for basic skill refreshment accounted for only a minor amount of training, even among part-time reservists at the 466th. Overall, the use of the AIT for switchology refresh was viewed by the AFRES operational squadrons as a relatively minor training benefit.

3. Fidelity. Pilots in the AFRES units were considerably more critical of AIT fidelity than those in the schoolhouse. There were significant and continuing complaints about oversensitivity of flight controls. The aerodynamics and engine simulation models had been checked and rechecked for accuracy with the aircraft. At length, expert opinion favored the view that the perception of control oversensitivity was due to a combination of two factors: (a) the difference between stick "feel" in the aircraft and that of the AIT, and (b) the absence of peripheral visual cuing in the trainer because of its limited field-of-view visual display. To simulate the effects of the aircraft stick force transducer in the AIT would have added greatly to the cost of the trainer. The potential training value of this enhancement to the AIT was judged to be worth much less than its high cost, so it was not added.

4. Design Enhancements. Simply stated, the AIT was not well utilized in the AFRES operational squadrons. Attempts to improve the performance of the trainer in order to meet the expectations of AFRES pilots in these units met with limited success. Except for switchology refreshment, AFRES pilots were not deriving substantial tactical training benefits at the time usage surveys were taken in the various units.

Study of the enhancement potential of the AIT spanned a three-month period in which AL/HRA interviewed subject matter experts to identify the specific improvements required by AFRES pilots to make the device acceptable. An initial list of capabilities was developed and then subjected to wider review among AFRES managers and pilots. The endorsement of experts developing the list came with the statement, "these changes, if properly implemented, would eradicate the perception of the AIT as a "lieutenant trainer" by challenging the skills and abilities of senior pilots." The list of capabilities, with descriptions condensed, appears below.

a. Addition of the Radar Homing and Warning (RHAW) scope to reflect true signatures of air-to-air threats. A beyond-visual-range (BVR), air-to-air threat warning would be required because of the lack of ground control intercept (GCI) information in the AIT.

b. Addition of "intelligent adversarial capabilities." This enhancement is subdivided into three aspects: (a) maneuvering capabilities, (b) adversary tactics, and (c) manipulation of target capabilities.

(1) Maneuvering capabilities. This refers to adversaries that respond as hostile aircraft employing BVR missiles, using tactics and missile parameters "similar to" those likely to be encountered in real-world combat situations.

(2) Adversary tactics. Users requested that adversarial capabilities resemble known aggressor tactics in unclassified versions. This was requested to permit AFRES pilots to practice against realistic BVR threats.

(3) Manipulation of target capabilities. As the third aspect of improved target capabilities, users requested a means of configuring the type and complexity of targets beyond those contained in the student instructor control system (SICS). This would permit pilots to select the type and level of tactics exhibited by the adversary as well as the number of opposing aircraft engaged in the sortie.

c. Addition of a "real aircraft" radar presentation. For the continuation training role, the trainer should present a realistically degraded radar image, with anomalies such as false targets, noise, limited range, track while scan error rates, and similar problems as encountered in the aircraft. None of these kinds of anomalies appears in the "idealized radar" version displayed by the AIT.

d. Addition of realistic HUD imagery. This enhancement is a corollary to the realistic radar described above. The head-up display would more closely correspond with what the pilots sees in the aircraft HUD. This would include such visual effects as "jitter" of the target designator box during intercepts, low fuel warnings, noise effects, and missile numbers.

e. Addition of "real aircraft" flight model. In the AIT training scenarios, the simulated aircraft was equipped with unlimited missiles and fuel, and highly "optimistic" aircraft performance capabilities. The performance of the operational aircraft is influenced by changes in gross weight, drag, center of gravity, etc. due to variations in stores and fuel. The purpose of this enhancement would be to make the trainer flight model more responsive in order to reflect more realistic changes in aircraft performance capabilities.

f. Addition of real-time missile fly-out capability. This fly-out capability would be as close to real-time as possible and would use classified weapons systems data.

g. Addition of the Stores Management Set (SMS) functions. The SMS permits the pilot to select and control various weapons delivery parameters via the multifunction displays. This capability in the trainer would significantly enhance tactical realism for the continuation training role.

h. Addition of Advanced Medium Range Air-to-Air Missile (AMRAAM) capability. This enhancement was primarily an "nice-to-have" item rather than a required training capability. It is related to the missile flyout capability. The addition of the AMRAAM would likely enhance the acceptance of the training device among experienced F-16 pilots.

Summary of Enhancements. Conceptually, the device with the above enhancements would be more appropriately termed an air radar tactics trainer, rather than an air intercept trainer. The design objective of the above list of enhancements would take the AIT well beyond the scope of its original design. Obviously, since these capabilities have not yet been developed, the issue of whether they would, in fact, enable AFRES pilots to achieve desired training goals can only be determined when and if they are developed and tested in an operational environment.

To put the AIT development issue in a wider perspective, recall when AFRES began experimenting with the AITs, there were three areas of training need: (a) emergency procedures, (b) instrument landings, and (c) air-to-air operations. Since the AIT only addressed part of the third need, the intention had been to eventually develop a training device capable of meeting all three requirements.

In this regard, the technology of the AIT and the experience using it in the AFRES squadrons became a point of departure for developing the new trainer. Planning and development for the new device, called the MultiTask Trainer (MTT), began soon after AITs were fielded in the AFRES. MTT technology was a direct extension of AIT design concepts and computer architecture. The MTT design evolved rapidly to the point of becoming the functional equivalent to the F-16 Operational Flight Trainer (OFT) with less visual system capability. Thus, the design enhancements listed above, as identified by AFRES pilots for the AIT, were more logically and efficiently embodied in the development of the MTT. As an interesting use of technology, however, the full software capabilities of the MTT became available for use in the advanced version of the AIT which became known as the AIT Plus and incorporated additional computer capacity to run the OFT software. The present plan is to use the MTT as the principal training device in the AFRES units with AIT Pluses as adjunct devices for some aspects of training.

5. Use of Two-Ship Mode. Data from the in-unit surveys showed that only about one fourth of AFRES pilots reported using the networked two-ship mode. This capability was designed to enable the engagement of one or more simulated enemy targets by one pilot in one AIT acting as flight lead and another pilot in the other AIT acting as the wingman. In some cases, two pilots used the two-ship mode to fly against each other as adversaries. This use of the device was regarded mostly as a novelty, with little useful training value, because operational sorties are based upon two-ship operations. Analysis of pilot opinion from interviews and questionnaires showed that the lack of pilot enthusiasm for the two-ship mode was mainly from the lack of ability to accomplish much meaningful training with it because of the limited capabilities of AIT scenarios. Further, to fly the two-ship mode, two pilots had to schedule time on the device jointly. Pilots reported frequent trouble getting the two trainers to operate reliably, and such attempts at training went unrewarded. Many pilots reported the value of the "two-ship" was not worth their time or inconvenience. Better reliability of the device was needed, but in the final analysis, this would not have solved the basic problem of training value inherent in the trainer.

6. Trainer Reliability and Technical Service. A number of trainer reliability problems surfaced with AIT deliveries to the first AFRES squadrons. These problems included initializing (booting up) trainers, miscellaneous radar malfunctions, overheating, and several mechanical problems. The overheating problem turned out to be persistent and required a design change in the AIT hardware. As training capabilities were added to the AIT from the original prototype, the number of computer boards and other internal components increased, adding to the heat load of the device and of the room in which it was operated. To provide improved reliability, it was necessary to redesign the cabinet interior to provide additional cooling capacity.

From the AL/HRA perspective, there were several requirements in minimizing equipment reliability problems for users. The first, and the most important, was to adopt a user-oriented view of device reliability. The second was to initiate and maintain frequent contact with the user. The third was to identify and correct problems as expeditiously as possible: the fourth, to document problems completely; and the fifth, to follow-up with users to verify resolution of problems.

7. Technology Transition. AL/HRA began transitioning AIT technology to the Training System Center of the Air Combat Command at Luke AFB in 1989. The basic agreement was that TSC would build the devices using hardware specifications and software provided by AL/HRA. The original intention had been for complete transition of

AIT technology, that is, all hardware and software functions so that TSC would be able to assume responsibilities for device manufacture, installation at user sites, maintenance and repair. Under this plan, AL/HRA would continue to develop and test new software and transition it to TSC.

Up to the advent of the AIT, TSC had been involved primarily in the development of training hardware, having produced a number of part-task practice devices which duplicated certain avionics functions of aircraft. Examples of F-16 training devices included a Fire Control and Navigation Panel (FCNP) Trainer and a Store Management Set (SMS) trainer.

The transition of the hardware function was successfully assumed by TSC. Replication of equipment cabinets, assembly of cockpit components, instruments, controls, and integration of computer hardware were well accomplished. TSC was able to make a number of improvements in the design and function of trainer hardware, including stick and throttle and cabinet cooling functions.

However, the AIT presented a substantial challenge to TSC in terms of software transition and maintenance. The complexity of AIT software was considerably beyond any of the systems previously manufactured by TSC. The level of software experience was less than adequate for this aspect of the transition. Difficulties became quite apparent when AL/HRA began transferring software upgrades. The laboratory standard for software "readiness" was apparently less stringent than TSC personnel were willing to accept. So a period of accommodation was required to work out differences and agree on standards for software transition. More difficult was the issue of software maintenance. It became clear that TSC was not in a position to maintain software. The result was that rather than affecting a complete transition of AIT technology to ACC/TSC, AL/HRA retained responsibility for device software maintenance. TSC as the point of contact for AIT maintenance, took the lead when field users (primarily AFRES units) required services. Under this arrangement TSC diagnosed needed repairs and when problems with software were identified, TSC referred them back to AL/HRA. During early fielding of devices to AFRES units, a large number of device malfunctions were attributable to software problems. The division of hardware and software maintenance responsibilities proved to be cumbersome and resulted in service delays because of the number of coordinations required to repair AITs (see related material in 6. Trainer Reliability and Technical Service, above).

8. ANG F-16 Conversion Training. In 1990, approximately 14 Air National Guard squadrons were identified for conversion from existing operational aircraft to the F-16. The conversion schedules spanned a period of about three years. Squadrons were sequenced through the F-16 conversion course which operated at the

184th FS, McConnell AFB, KN. The ANG schoolhouse made extensive use of the AIT in its conversion course syllabus. Three AITs were located at the squadron to support training. Evaluation of AIT use at the ANG schoolhouse confirmed that benefits from the trainer were essentially the same as those observed in the ACC schoolhouses at Luke and MacDill AFBs.

Several converting units also made use of the AIT to familiarize pilots with air intercepts prior to attending the conversion course at McConnell AFB. The first squadron to use the device for this purpose was the 120th FS at Buckley ANG Base, CO. To implement the trainer, a special in-unit training syllabus was developed around the capabilities of the AIT. All unit pilots received up to six hours of training on the device prior to attending the conversion course. Pilot grade slip records examined at the schoolhouse showed that pilots who received the AIT training prior to the course received significantly higher instructor ratings on simulator and aircraft air-to-air training sorties compared to pilots who had not received the AIT training.

Following the demonstrated success of the squadron-based AIT training, several other ANG units obtained AITs for use by their pilots prior to attending the conversion course. Some of these units were able to obtain AITs on loan from AFRES units.

REVIEW OF LESSONS LEARNED BY TECHNOLOGY TRANSITION ISSUES

At the beginning of this report, a list was provided of several issues to be addressed as part of the study of AIT technology transition. The purpose of this final part of the report is to group the lessons learned according to their relevance to transition issues. The headings listed below are the transition issues with pertinent lessons learned summarized in single paragraphs below each heading. In some cases, lessons learned may be listed under more than one transition issue depending upon relevance to more than one area.

1. Device Acceptance by Users

The training capabilities and utility of the AIT were well accepted by the Air National Guard training squadron and the device became a key training resource during conversion to the F-16A aircraft from the A-7D aircraft.

The prototype AIT was not equipped with a forward view, out-the-cockpit, visual display. While the initial reaction of ANG student pilots to this limitation was negative, the training effect was positive. The "forced" reliance on HUD/radar information during training produced substantial skill gains in intercept geometry and situational awareness, as reported by instructor pilots.

ANG pilots found the lack of pilot-controllable, simulated flight of the prototype AIT unacceptable. As a result, AL/HRA promptly developed and retrofitted enhanced flight control capabilities.

The AIT was well accepted in the ACC schoolhouse community as an introductory level air-to-air training device. It filled an important training need in the B course. The effectiveness of the AIT and its acceptance were the result of extensive training analysis and design, technology development, and long-term efforts to improve device training qualities, including application of lessons learned from experience with the ANG.

Instructor pilots (ACC schoolhouse) accepted the AIT as a useful training resource. This was attributable to the AIT's training software capabilities, compatibility with syllabus objectives and content, and the convenience to students afforded by the presence of the AIT in the academic squadron.

2. Usage Methods and Patterns

ANG pilots required substantially improved training in HUD/radar interpretation skills as a lead-in to the AIT phase. Lack of these enabling skills caused AIT training to be much less efficient than it should have been during the first several classes. This led to revision of the training syllabus to provide more AIT time for basic skills development and eventually led to the development of additional training materials.

Assessment of pilot performance of intercepts was better accomplished using well-developed debriefing feedback techniques, rather than a computer scoring approach. The development of a linear scoring system which assigned weighted values for various intercept components proved inadequate for purposes of training evaluation.

The training utility of the AIT for switchology skills maintenance corresponded with pilot experience (in AFRES squadrons).

ANG squadrons converting to the F-16 found the AIT advantageous as a familiarization device in squadrons and as part of the conversion course syllabus at the schoolhouse. Some of the AFRES units relinquished their AITs for use by ANG units.

3. Design Features and Options

ANG pilots found the lack of pilot-controllable, simulated flight of the trainer unacceptable. As a result, AL/HRA promptly developed and retrofitted enhanced software to provide acceptable flight controls. Device training utility and pilot acceptance increased following this upgrade. The resulting lesson for AL/HRA was that any aircraft capabilities included in the simulation must be functionally equivalent to the aircraft. Or, if present in the device, they must be of such obviously low fidelity that pilots are not led to equate trainer capabilities with those of the aircraft.

Student pilots (in the ACC schoolhouse) were able to successfully use the training menus, instructional features, and practice scenarios without the assistance of an instructor pilot. Students generally preferred the self-paced mode of training on the AIT as a means toward developing intercept skills. Instructors also accepted the self-paced mode of use.

To support AFRES operations squadrons, device capabilities would extend well beyond those of the AIT. In view of this finding, the magnitude of needed changes and associated costs, the reasonable choice would be a new trainer design, rather than a modified AIT.

Although the networking capability of two AITs for two-ship operations was developed as a training enhancement for the AFRES squadrons, pilots in these units made little use of this feature. Related to this finding was the fact that pilots preferred to use the AIT by themselves. Pilots also reported having problems using the two-ship mode.

4. Training Capabilities and Effectiveness

ANG students required considerable instructor assistance to learn basic operation of the AIT. However, once students were familiar with the equipment and could "navigate" within the software, self-paced practice on the device became a realistic option.

The prototype AIT was not equipped with a forward view out-of-the-cockpit visual display. While the initial reaction of ANG student pilots to this limitation was negative, training effectiveness was positive. The resulting "forced" reliance on HUD/radar information during training produced substantial skill gains in intercept geometry and situational awareness, as reported by instructor pilots.

For experienced F-16 operational pilots in the AFRES operational squadrons, the training utility of the AIT was limited. Even with enhancements in the capabilities of the trainer, pilots were able to realize relatively minor training benefits from the AIT such as basic switchology skill refreshment.

Limitations in AIT fidelity and training capabilities which were acceptable in the schoolhouse were found to be unacceptable to operational pilots in AFRES units, particularly in units where pilot experience was high. Data collected in these squadrons showed that once a pilot had accrued about 300 hours in the aircraft, the value of AIT training became negligible.

5. Device Reliability

The operational reliability of the AIT from its beginnings ANG had been exemplary. However, as the trainer evolved and its complexity increased, so did reliability problems. By the time the AITs had evolved to the AFRES application stage, reliability problems had become considerable and required special attention. Better technical service to users, particularly during the initial period of use at the unit, could have alleviated trainer reliability problems and promoted better user acceptance in the squadrons. This was especially true for the first AFRES squadrons who received the AITs.

6. Technology Development Process

The development and delivery of timely, yet state-of-the-art training technology directly from AL/HRA to the user presented a dilemma. The prototyping process had to accommodate timely infusion of new technology, otherwise, the trainer would be obsolete upon delivery. However, if technology infusion dominated development, the effort would become consumed "chasing" technology so that a usable device would never be delivered. A balance was reached by developing a two-step prototyping process which made possible timely infusion of technology into the trainer design.

7. Technology Transition Process

Findings from an initial AIT empirical evaluation ANG training were inconclusive relative to AIT training effectiveness. Subsequent trainer evaluation required substantially improved experimental methods and procedures to insure useful and reliable results.

Fully transitioning the prototype AIT from the laboratory to the user/manufacturer was not possible because of inability to assume responsibilities for software development, upgrades, and maintenance.

ANG F-16 squadrons found the AIT advantageous as a familiarization device in the squadrons and as part of the conversion course syllabus at the schoolhouse. Some of the AFRES units relinquished their AITs for use by ANG units.

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